BaSeL: a library of synthetic spectra and colours for GAIA

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Abstract. The BaseL Stellar Library (BaSeL) is a library of synthetic spectra which has already been used in various astrophysical applications (stellar clusters studies, characterization and choice of the COROT potential targets, eclipsing binaries, ...). This library could provide useful indications to 1) choose the best photometric system for the GAIA strategy by evaluating their expected performances and 2) apply systematically the BaSeL models for any sample of GAIA targets. In this context, we describe one of the future developments of the BaSeL interactive web site to probe the GAIA photometric data: an automatic determination of atmospheric parameters from observed colours.

1. Brief description of the BaSeL model and its interactive server

The Basel Stellar Library (BaSeL) is a library of theoretical spectra corrected to provide synthetic colours consistent with empirical colour-temperature calibrations at all wavelengths from the near-UV to the far-IR (see Lejeune et al. 1997, 1998 for a complete description, and Westera et al. 1999 for the most recent version). These model spectra cover a large range of fundamental parameters ($2000 \leq T_{\rm eff} \leq 50{,}000$ K, $-5 \leq$ [Fe/H] ≤ 1 and $-1.02 \leq \log g \leq 5.5$) and hence allow to investigate a large panel of multi-wavelength astrophysical questions, as briefly reviewed in the next section. Since they are based on synthetic spectra, they can in principle be used in many photometric systems taken either individually or collectively, and this is another major advantage of these models. The "BaSeL interactive server" is the web version of the BaSeL models (`http://www.astro.mat.uc.pt/BaSeL/`). This server is under development and the photometric systems presently available in interactive mode are:

Geneva, Washington, Johnson-Cousins, Strömgren, HST-WFPC2, photographic RGU, and EROS. All details about this server will be given elsewhere.

2. Astrophysical applications

The BaSeL models are currently used in an increasing number of astrophysical studies. It is far beyond the scope of this work to cite all the studies but some examples of application cover globular clusters (e.g. Bruzual et al. 1997, Weiss & Salaris 1999, Kurth et al. 1999, Lejeune & Buser 1999), open clusters (e.g. Lastennet 1998, Pols et al. 1998), preparation of the COROT space mission (Lastennet et al. 2001a), HR diagram of the Hyades (e.g. Lastennet et al. 1999b, Lebreton et al. 2001), blue stragglers (e.g. Deng et al. 1999), AGB stars (e.g. Lastennet et al. 2001b), eclipsing binary stars (e.g. Lastennet et al. 1999a), stars in the Small Magellanic Cloud (Cordier et al. 2000), and clusters of galaxies (e.g. Steindling et al. 2001). Moreover, the photometric systems available in BaSeL can be used independently (e.g. the photographic RGU system, Buser et al. 2000) or collectively (e.g. Johnson *and* Strömgren, Lastennet et al. 2001a). Finally, the BaSeL library has been used recently to evaluate the performance of the proposed GAIA photometric system 3G (Sudzius et al. 2001).

3. The GAIA mission

The GAIA mission, with a launch date in 2010-2012, is an approved Cornerstone mission by ESA designed to solve many of the most fundamental challenges in astronomy: to determine the composition, formation and evolution of our Galaxy. The core science case for GAIA requires measurement of luminosity, effective temperature, mass, age, and composition for the stellar populations in our own Galaxy and in its nearest galaxy neighbours. These quantities can be derived from the spectral energy distribution of the stars, through multi-band photometry. Because the GAIA photometric system must be able to classify stars across the entire HR diagram, as well as to identify peculiar objects, none of the existing photometric systems satisfy all the GAIA requirements, and a new system has to be defined (standard wavebands and sets of standard stars). Moreover, a recent study from the Vilnius GAIA group (Vansevicius et al. 2001), comparing the performance of the proposed GAIA photometric systems 1F, 2A & 3G, seems to indicate that no optimal photometric system for GAIA is proposed to date. Covering a large spectral domain, extending from the UV to the far-IR, BaSeL is adapted to perform simulations with the (new) proposed photometric systems, and should help to choose the most efficient one.

4. One of the future developments of the BaSeL web site for GAIA

In its actual version, the BaSeL models can already provide relevant information to select between the proposed GAIA photometric systems. Given a set of effective temperature, metallicity and surface gravity ($T_{\rm eff}$, [Fe/H], log g), the BaSeL models provide colours that can be directly compared with photometric observations of stellar populations. Alternatively, the inverse method

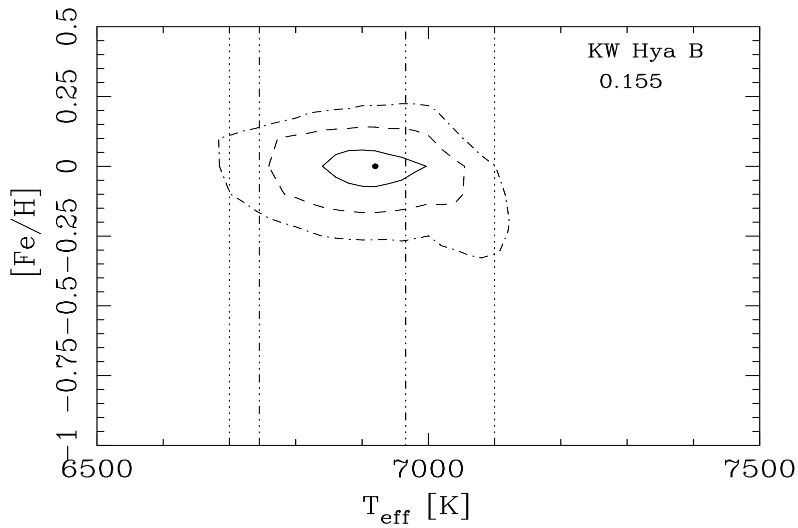

Figure 1. Simultaneous (T_{eff}, [Fe/H]) determination for the star KW Hya B (secondary component of an EB) from Strömgren photometry. Confidence regions (1, 2 and 3-σ) are derived from the synthetic BaSeL photometry. An estimation of the quality of the best fit (χ^2-value) is quoted in the right upper corner. The T_{eff} from Andersen (1991) (vertical dotted lines) and Ribas et al. (2000) (vertical dot-dashed lines) are also shown for comparison.

(Lastennet et al. 1999a, LLWB99) would be very useful to derive the atmospheric parameters *from* the observed colours. LLWB99 applied this method to derive simultaneously the T_{eff} and metallicity of a sample of eclipsing binary stars (EBs) with photometric data in the Strömgren system. They obtained very good results from the BaSeL models, in agreement with the T_{eff} derived from accurate HIPPARCOS data and with spectroscopic determination of metallicity (when available). However, while they fix log g because this quantity is known with an excellent accuracy for their sample of EBs, we intend to use a more general χ^2-minimization algorithm for the GAIA targets in order to derive the 3 atmospheric parameters:

$$\chi^2(T_{\rm eff}, [Fe/H], log\, g) = \sum_{i=1}^{n} \left[\left(\frac{\mathrm{GPI(i)_{syn}} - \mathrm{GPI(i)}}{\sigma(\mathrm{GPI(i)})} \right)^2 \right], \tag{1}$$

where n is the number of photometric indices, GPI(i) is a selected **G**AIA **P**hotometric **I**ndex and $\mathrm{GPI(i)_{syn}}$ is the BaSeL synthetic index in the GAIA photometric system. The uncertainty on the index measurements - σ(GPI(i)) - will provide confidence contours on the (T_{eff}, [Fe/H], log g) results. The interstellar absorption can either be included in equation (1) as an additional parameter (see an example in LLWB99, sect. 3.3.2) or can be determined by independent methods (see e.g. Lastennet et al. 2001a). An obvious advantage of this algorithm is to know the quality of the fit: an example is given in a T_{eff}-[Fe/H] diagram (Fig. 1) where comparisons with previous T_{eff} determinations show a good agreement. Note that the BaSeL models also provide an [Fe/H] determination in Fig. 1. Other examples, including bad fits, can be found in Lastennet

et al. (1999a, 2001a). In the context of the GAIA mission, we propose to develop an automatic tool based on this extended method of Lastennet et al. to complete the facilities of the *BaSeL server*. Provided that the new GAIA passbands (e.g. for the 1F system: 4 broad and 11 intermediate bands covering the spectral range 280 to 920 nm) are implemented in the BaSeL models, this new tool will provide automatically ($T_{\rm eff}$, log g, [Fe/H]) estimates and uncertainties for the stars observed with the GAIA photometric bands. An automatic and efficient treatment of any sample of GAIA targets will be possible.

5. Conclusion

Covering a large spectral domain, extending from the UV to the far-infrared, the BaSeL models are adapted to perform simulations with the proposed GAIA photometric systems and should help to choose the most efficient one. We present and discuss a proposition to develop an automatic method, already used with success for COROT potential targets (Lastennet et al. 2001a), for a systematic determination of fundamental parameters from BaSeL synthetic multi-photometry. This new tool should be publicly available in 2002 on the following web site `http://www.astro.mat.uc.pt/BaSeL/`.

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